UPPER WIND-CURRENTS NEAR THE EQUATOR, AND THE DIFFUSION OF KRAKATÃO DUST.

THE crude idea that the trade-winds on either side of the equator met in the doldrums, and that then the air rising upwards flowed backwards as a return south-west current in the northern hemisphere, and as a north-west current in the southern hemisphere, has been modified by the more modern discoveries that the atmosphere is not composed of horizontal layers of air moving in different directions, but that, as a rule, there is a regular continuous successive veering of the wind as we ascend. It is not usual to find a southerly wind on the surface, and for some height above, and then abruptly a westerly current also of a certain thickness; for cloud-observations show that over a surface south wind the upper currents may be from south-by-west at quite a low level, from south-south-west a little higher up, then successively from south-west and west-south-west as we ascend, and perhaps from west at the altitude of the highest cirrus. We must, in fact, look upon the atmosphere as circulating in the form of a continuous complex screw.

Innumerable observations show that, as a rule, there is a very definite law of the vertical succession of the upper currents. Stand with your back to the surface wind, and the upper currents will come successively more and more from your left hand the higher they are. The rule is reversed in the southern hemisphere, for there the upper currents come successively more and more from the right. For instance, with a southerly wind in London the clouds will come more and more from the west the higher they are, while in Australia they would come more and more from the east.

But during my two meteorological voyages round the world I have discovered some very remarkable exceptions to this law in that interesting part of the world, meteorologically, that lies between the equator and the doldrums. These have so important a bearing, not only on the whole problem of the circulation of the atmosphere from the equator to the Pole, but also on the remarkable diffusion of dust from the volcano of Krakatão, that I propose to give a short account of these researches in this article.

In the Atlantic, the doldrums lie north of the equator at all seasons of the year. Between 20° and 30° W. longitude they range from about 3° N.; in winter, to 11° N. in summer time. In the Gulf of Guinea, the position of the doldrums cannot be accurately defined, but they probably range from about 5° to 10° N. of the equator. There is, however, a striking difference in the direction of the winds between the equator and the doldrums in the eastern and western portions of the Atlantic. In the Gulf of Guinea, the south-east trade turns to south-west and forms a south-west monsoon; while west of about 15° W. longitude the south-east trade remains from nearly in the same direction as before it crossed the line.

In the Indian Ocean, the position of the doldrums varies enormously at different seasons. From about November to March the doldrums are 5° to 10° S. of the line, and the north-east monsoon draws into the well-known north-west monsoon as it crosses the equator. From April till September the doldrums must be somewhere to the north of the line; but, contrary to the opinion of Dove and others, the Indian meteorologists now believe that the south-west monsoon is not linked up regularly with the south-east trade. As the evidence for this belief is not yet published, we can say nothing about it, though we shall have to refer to the point later on.

The words rotation, circulation, and veering of wind are unfortunately used so vaguely by different writers that it may be well to define them more precisely before we discuss the general circulation of the equator.

"Rotation" should be confined exclusively to the manner in which the surface wind blows round areas of high or low pressure. For instance, we may say that the wind rotates counter-clockwise round a cyclone in the northern hemisphere.

"Circulation" should be applied to the general movement of a whole mass of air extending over a certain breadth and height. For instance, the air in a cyclone rotates round and in below, round and out at high levels; and the whole system makes up the general circulation of a cyclone. Or, again, the whole motion of the atmosphere into the doldrums, then upwards and more or less polewards, should be called the general circulation in the vicinity of the equator.

"Sequence" of wind should be applied to the changes in the direction of the wind which take place during any interval of time as a cyclone passes over a station. This veering or backing of the wind has unfortunately been too often called the rotation of the wind. The confusion here, as often, arises from sometimes talking of the motions of a mass of air extending over a large area at a given moment, and sometimes of the successive motions of the air at a single station during a certain interval of time. Some writers make matters worse by not only drawing the plan of a cyclone on a chart, but also by putting in small circles at different stations to show how the wind would go round as the cyclone drifted past. The confusion is direful.

"Vertical succession" should be used to denote the gradual successive directions of the upper currents, as has been already explained.

The two sections of weather across the Atlantic which I made were taken, the one in July, between Rio Janeiro and Teneriffe; the other in December, between Teneriffe and Capetown. A short account of the observations were published in NATURE, vol. xxxiii. p. 294, so that the general results only need be stated here.

Between Rio and Teneriffe, while south of the line, the low or middle clouds over the south-east trade invariably came from some point to the right of the surface when you stood with your back to the wind; *i.e.* if the surface wind was south-east the low clouds would drive from about east-south-east. This is the usual vertical succession of the southern hemisphere.

But north of the line, when, for reasons which cannot be discussed here, the south-east trade did not turn into south-west, as might have been expected, the upper currents continued to follow the succession of the southern hemisphere, instead of conforming to the law of the northern hemisphere. In the doldrums, which extended from about 8° to 13° N., the same rule obtained, and the middle layer of cloud over some "cats' paws" of south-east wind drove from the east. To show how difficult it is to get cirrus observations in the tropics, I may mention that this was the highest layer I was able to record during this part of the voyage.

In the north-east trade I only got one unsatisfactory observation in 22° N., 19° W., which gave a middle layer of north-north-east wind over an east-north-east surface trade. This is the contrary of what might have been expected.

In the second section, between Teneriffe and Capetown, the lower layers of cloud in the north-east trade—from 30° N. to the doldrums in 5° N.—invariably came from some point to the left of the surface wind, generally from south or south-by-west. This is the usual vertical succession of the northern hemisphere.

But as we entered the doldrums, in 5° N., a totally different wind-system became apparent. Over the oily calm of that district I could just detect, through the universal haze and gloom, a middle current from the east; and when a few hours later we picked up the south-west monsoon of the Gulf of Guinea—here coming from south-by-west—the low clouds came from south-east. This continued till we reached the line, and the single observation that I got of high cirrus in 1° N. lat. showed an easterly current at that level. The above results are very curious, for the usual idea is that the south-east trade on crossing the equator becomes a south-west wind under the influence of the earth's rotation ; but here, though the surface wind appears to conform to the usual rotation of the air round a low pressure, the upper currents maintain the vertical succession of the southern hemisphere.

After crossing the equator ourselves, the wind turned to south-by-east, or south-south-east ; and as far as 18° S., beyond which we need not follow them, the lower currents were either identical in direction with the surface winds, or else a very little more easterly—that is, they followed the normal vertical succession of the southern hemisphere.

I have endeavoured to show all this in a diagrammatic form in Fig. 1, where the full arrows denote the surface wind ; the broken-lined arrows the direction of the low or middle-level clouds ; the dotted arrows that of the highest cirrus. A couple of arrows to denote the typical succession over an extra-tropical south-west wind are inserted on the upper left-hand corner of the figure.

The observations in the Indian Ocean have also been published in NATURE, vol. xxxii. p. 624, and vol. xxxiii. p. 460. They were taken during two trips—one from Aden to Cape Lewin, in February, the other from Cape Lewin to Colombo, in the same month of the following year. This is the season of the north-west monsoon. The results were very accordant, and showed conclusively that in vertical succession the upper currents over the north-east monsoon were always more from the east than the surface wind, as is usual in the northern hemisphere. No high cirrus was ever observed in this part of the ocean.

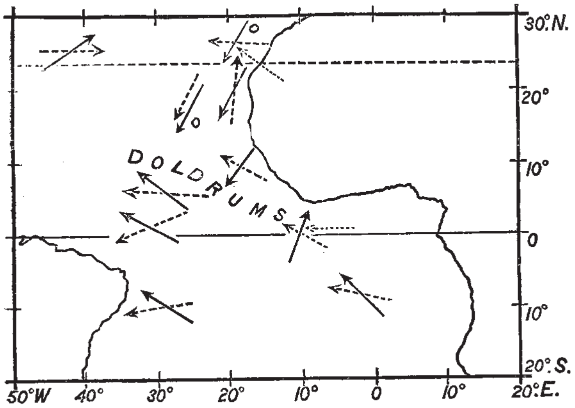

FIG. 1.—Surface and upper currents in the Atlantic.

In the north-west monsoon, between the equator and the doldrums, low and middle currents came from north or north-east, and the only two observations on the highest cirrus showed an easterly current at that level.

In the south-east trade, the low or middle currents were generally about from the same direction as the surface wind, or else a little more from the east. This is the normal succession of the hemisphere. Thus we see an extraordinary analogy to what occurs in the Atlantic. When the north-east monsoon is drawn across the equator, towards the low pressure of the doldrums, the surface wind seems to pick up the westerly component of the earth's rotation in the usual manner ; but the upper currents retain the vertical succession of the northern hemisphere.

The results of all the observations are given in a diagrammatic form in Fig. 2. It will be remarked how few observations there are of cirrus ; this is because it is so rarely seen in those latitudes. It is certain that, on the southern and western edges of the great anticyclone which controls the south-east trade, the highest currents would have come more or less from the north-west, as is marked at Mauritius.

I have unfortunately got no equatorial observations from the Pacific, but they would most likely be very similar to those in the Atlantic.

However, the upshot of all those which we have just described is to show that when the trades or monsoons meet they do not interlace, as has been suggested by Maury, but that the upper winds combine in a generally easterly current, and probably diverge only slightly polewards on either side. I am unable to form any opinion as to the velocity of this current.

I have often been asked how far all this bears on the remarkable distribution of dust from Krakatão, and the answer is very simple. The great explosion of Krakatão took place on August 26 ; that is to say, during the south-west moonsoon of the Indian Ocean. The distribution of the surface and upper currents is then very different from that in our last diagram. The south-east trade, with its upper easterly currents, extends all over the Indian Ocean, and Malaysia south of the line, including Krakatão, marked K in the figure. North of the equator the surface wind turns to the south-west, but we know nothing of the motion of the upper currents.

Now, assuming that the blue sun and unusual twilight glows were equally the product of volcanic dust as the fall of actual ashes, the sequence of the first appearance of these phenomena in different parts of the world, dating from August 26, was as follows :—

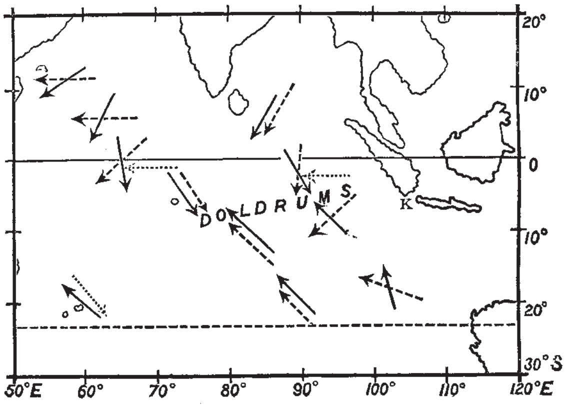

FIG. 2.—Surface and upper currents in the Indian Ocean in February.

On August 26, the day of the eruption, ashes, lofty haze, or red twilights are reported south of the equator, nearly 20° of longitude west of Java, from one station in Sumatra, just north of the line, and from near Formosa.

Next day, the 27th, similar phenomena were reported from many stations in the Indian Ocean, south of the equator, as far west as Mauritius and the Seychelles ; while north of the line, strange appearances were reported for the first time in Borneo and Ceylon.

On the 28th, the haze and abnormal glows had extended to Natal on one side and Japan on the other.

No important extension of the area is reported on August 29 ; but by the 30th unusual coloration of the sky is reported from various parts of the South Atlantic, and Guiana, and, what is specially noticeable, from about the Cape Verd Islands, north of the equator.

On the 31st, another station in Brazil, and also a West Indian island, report a strange look about the sun or sky ; while on September 1 the same was noted at Guayaquil, on the west coast of South America ; and in a quite unexpected locality, far away from there,—New Ireland.

September 2 was characterized by an outburst of coloured suns all over the northern provinces of South America; while between the 3rd and 4th of the same month the glows extended across the Pacific both north and south as far as the Society and Gilbert Islands, and were reported from two stations in New Britain.

By September 5 the Sandwich Islands were reached; while the outburst of glows in Southern India did not commence till about the 6th to 8th of the same month.

The northward extension of the dust all this time was very small, and not widespread. Isolated phenomena are reported from Formosa on August 26, and from Japan on the 28th, but I am unable to say whether the glows which appeared in the Sandwich Islands on September 5, had come *viâ* Japan, or across South America.

Thus the general system of the dust-flow appears to have been very simple. The great dust-stream was carried for the first twenty-four hours by the normal easterly upper currents over the south-east trade, at the extraordinary rate of more than 120 miles an hour, but hardly extended north of the line. Three days after the eruption we find the products of Krakatão in Guiana, the South Atlantic and also north of the line in the Cape Verd Islands. Just to the south of the latter we know that the south-east trade with its attendant upper currents crosses the equator. Then all the north of South America was invaded; and six or seven days after the first outburst, the Pacific Islands—south of, or on the line—were also overshadowed.

In fact we may say that the great stream of Krakatão dust was carried nearly round the world by the usual upper winds of the south-east trade, in which the dust was first ejected, at a rate of about 120 miles an hour, and that the dust spread very slowly either north or south of the main current.

There is one inference from this which is very important in any theory of the general circulation of the atmosphere from the equator to the Poles. The main body of the equatorial circulation is in an easterly direction, so that the whole mass of air going towards the doldrums does not rise up and flow backwards on itself directly towards the Pole; and though the highest currents over the Polar limit of both the south-east and north-east trades are from north-west and south-east respectively, still the poleward motion near the equator is very small.

The high velocity of 120 miles an hour is certainly more than would have been expected; but we have very few observations on the rate of motion of the highest clouds. Hildebrandsson has, however, reported from Upsala one velocity of about 112 miles per hour for a cirrus at 28,000 feet (50 metres per second at 8559 metres); and several velocities ranging between that figure and 90 miles per hour.

There would be nothing, then, outrageous in the assumption of a velocity of 120 miles an hour for the easterly current over the equator to account for the high speed of the diffusion of Krakatão dust; and it is also satisfactory to know that the general direction of the flow is in accordance with the most recent researches on the vertical succession of the upper currents near the equator.

RALPH ABERCROMBY.

BERNARD STUDER.

AMONG the magnates of Swiss geology, no name has held a more honoured place than that of Bernard Studer, who now at the ripe age of ninety-three years has passed away. Upwards of sixty years ago he began his scientific career by the study of some of the geological problems presented by the rocks of his native country. From the molasse of the lower grounds he soon climbed into the higher Alps, and distinguished himself as one of the foremost pioneers who grappled with the intricate problems in stratigraphy which these mountains present. With patient toil he extended year by year his acquaintance with the various portions of the chain, publishing from time to time notices of his labours, and preparing materials for a geological map of the whole region. In association with A. Escher von der Linth he pursued these labours until the two fellow-workers were enabled to give to the world their great map of Switzerland, which, though only an outline of the geology of the Alps, will remain as an enduring monument of the geological prowess of its authors. No one who has not climbed the mountains with that map in hand can form any adequate conception of the physical labour, mental exertion, and happy geological intuition which its preparation required.

Studer's contributions to the glacial geology of the Alps brought him into intimate personal relations with many English geologists. All who passed through Berne tried to see the venerable Professor, who retained, in spite of his weight of years, his keen interest in the progress of his favourite science. His papers, published in various scientific journals, make a long list. But he was also the author of some separate works. Besides the great map of Switzerland, he published several volumes on Swiss geology, the most important of which was his "Geologie der Schweiz," which appeared in two volumes in 1851-53. Less known perhaps, but full of suggestive matter, is his "Lehrbuch der physikalischen Geographie und Geologie," which was issued as far back as 1844. This work was one of the earliest in which the processes of physical geography were discussed from the geological side, and showed how wide and thoughtful had been the observations of the author, especially among the phenomena to be witnessed in Switzerland. Another of the old lights of geology has been extinguished by the death of Bernard Studer, whose kindly presence and helpful courtesy will be affectionately remembered by everyone who has been fortunate enough to come in contact with him.

NOTES.

AN important Bill dealing with the question of technical education has been introduced into the House of Commons by Sir Henry Roscoe. The Bill empowers any School Board, local authority, or managers of a public elementary school, to provide day technical and commercial schools and classes for the purpose of giving instruction in any of certain subjects. These include the several science subjects which are specified in the Directory of the Science and Art Department, and in which that Department undertakes to examine. The following subjects are also included: the use of ordinary tools, commercial arithmetic, commercial geography, book-keeping, French, German, and other foreign languages, and freehand and machine drawing. The addition of other subjects may be sanctioned from time to time by the Committee of Council on Education or by the Science and Art Department. For the purpose of carrying on these schools and classes, the power of School Boards, other local authorities, and school managers is to be in every respect the same as for providing ordinary elementary schools. They are to have power to provide, or contribute to the maintenance of, laboratories and workshops in endowed schools for the purpose of carrying on classes or instruction under the Bill. All these schools and classes are to be subject to the inspection of the officers of the Committee of Education or of the Science and Art Department. Before a scholar is admitted he must have passed the Sixth Standard or some equivalent examination. The Education Committee and the Science and Art Department are authorized to give grants on such conditions as they may lay down for any of the subjects taught. For the purpose of obtaining grants a technical school or class must be one carried on under minutes to be made by the